Research on the environmental impact of weeds in Australia

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Summary Hobbs and Humphries (1995) recommended that research on plant invasions should be directed at the ecosystem effects of invasions. Adair and Groves (1998) summarised the studies undertaken before 1995 on the environmental impacts of weeds in Australia. They referred to eight weed species known to affect ecosystem function and listed 21 quantitative studies of the impact of weeds on biodiversity. Since 1995 the number of quantitative studies of the impact of weeds on the Australian environment has more than doubled to over 70, covering 30 species. Most Australian studies, in common with the international trend, show that weeds are associated with a loss of plant biodiversity, expressed as both a reduction in native species richness and changes in community composition and structure. However, complex relationships emerge following invasion by some weeds and there is a wide knowledge gap as to which are transformer species (Richardson *et al.* 2000). Weed invasion is considered to be a threatening process for a third of rare species in Australia. There is almost no quantification of this threat, nor an assessment of its relative importance. The measures currently adopted to understand the invasion of weeds in Australia are not at the level required to plan for strategies to mitigate the problem.

Keywords Environmental impact, invasive plant, weeds, Australia.

INTRODUCTION

Over a decade ago Hobbs and Humphries (1995) recommended that research on plant invasions should be directed at the ecosystem effects of invasions. Although these effects are frequently alluded to, there are remarkably few good data with which to inform policy-makers and funding bodies. Adair and Groves (1998) summarised the studies undertaken before 1995 on the environmental impacts of weeds in Australia. They referred to eight weed species known to affect ecosystem function in Australia and listed 21 quantitative studies of the impacts of weeds on biodiversity, covering the years up to and including 1995. Williams and West (2000) summarised the progress, during the subsequent five years, towards understanding ecosystem effects and listed four studies in this field. They pointed out that an increased knowledge of the ecology and biology of environmental weeds is required for improved management in natural ecosystems.

Since 1995, and in particular since 2003, there has been an increase in Australian studies of the environmental impacts of weeds (Figure 1). The subject of invasion ecology has become popular internationally (Byers *et al.* 2002). This mini review examines the scientific literature which concerns the environmental impact of weeds in Australia.

MATERIALS AND METHODS

Publications on the environmental impact of weeds were located by key-word searches of the main scientific databases, concentrating on publications after 1995. Earlier work is listed in Adair and Groves (1998). Only broad trends are discussed here and a more detailed analysis will be published elsewhere.

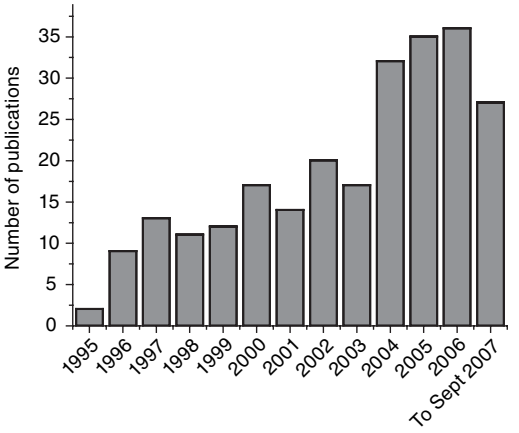

Figure 1. Number of publications on the environmental impact of weeds. (Search terms in Web of Science, CABI and Current Contents databases were invasiv* and plant* or weed*; Australia* and impact* or ecol* or environ*).

IMPACT ON BIODIVERSITY STRUCTURE

The majority of studies that were published sought correlations between the presence/absence of a single weed species and the composition of the invaded community. Most commonly, this was done by comparing weed-invaded with nearby weed-free areas. The predominant measure of community impacts was plant species richness. Less attention was given to quantifying the effects of weeds on fauna. These correlative approaches have generally not attempted to examine the processes underlying the differences that are observed. Where it has been examined, the correlation between weed presence or abundance and plant species richness is generally negative.

The results from faunal work using similar approaches are far more variable. There may be positive, negative or no correlation between weed presence/abundance and the abundance of different higher order faunal taxa. Furthermore, different functional groups or guilds within these higher order taxa may respond in quite different ways and different weed species may elicit quite different responses. This complexity makes it more difficult to extract generalisations.

IMPACT ON BIODIVERSITY FUNCTION

With the emphasis on correlative approaches to examining the impacts of invasive species on native species, communities and ecosystems, relatively little effort has been put into quantifying the processes involved. Two species have been the subjects of studies of the mechanisms of impact of grasses that are invasive in northern Australia. These are gamba grass (*Andropogon gayanus*), and mission grass (*Pennisetum polystachion*). Research on gamba grass and mission grass has focused on quantifying their impacts on fire regimes and soil processes (Rossiter *et al.* 2003, 2004). These species lead to higher intensity fires because they produce high biomass that cures later in the dry season compared with native grasses. Data also indicate that impacts of gamba grass are mediated by the species' influence on soil nutrient levels, in particular, reducing soil nitrogen and soil moisture. This example demonstrates that, when a plant species invades, several mechanisms can operate simultaneously to influence different aspects of the native environment and the community it supports.

There are many other mechanisms whereby invasive plants could conceivably affect native species, communities and ecosystems. These include mechanisms involving: plant × plant interactions, such as competition for resources; allelopathy and habitat alteration; and plant × animal or microbe interactions that involve changes to resource availability. In general, though, the mechanisms of impact have been little studied.

IMPACT ON RARE AND ENDANGERED SPP.

Leigh *et al.* (1984), in a major national review of extinct and threatened plant species in Australia, list competition from other plants as a major threatening process. At that time they noted that two species had become extinct and 55 endangered by competition from weeds. Leigh and Briggs (1992) and Burgman (2002) listed weed competition as the presumed cause of four extinctions, a past threat to twelve endangered species and a present and future threat of 57 endangered species. Weeds and road works ranked as the second most important among some 27 categories of threat (Leigh and Briggs 1992). Subsequently Vidler (2004) listed at least 29 plant species, 4 birds, 1 reptile, 3 mammals and 4 butterflies as threatened by weeds.

However, weeds posed a threat to about 45% of the 945 listed threatened species (271 animal species and 569 plant species), 72 Endangered Ecological Communities and 33 Endangered Populations in New South Wales (Coutts-Smith and Downey 2006). Half of these are listed under the Federal Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act). Extrapolating from the NSW information, it is likely that a third of rare or threatened species nationally will have weeds as an identified threat. Indeed, Burgman *et al.* (2007) in an analysis of 524 species listed under the EPBC Act identified weeds as a past threat to about 30 species and a future threat to approximately 175 species (33%).

DISCUSSION

Even at the international level there are very few papers that quantify the ecological impacts of weeds. Levine *et al.* (2003) reviewed over 150 studies (seven involving Australian situations) that evaluated the mechanisms underlying the impacts of exotic plant invasions on ecosystem structure and function. They found that numerous studies examined the impacts of invasions on plant diversity and composition, but less than 5% tested whether the effects were due to competition, alteration of ecosystem variables, allelopathy or other processes. Competition was most often hypothesised and nearly all studies found strong competitive effects of exotic species.

Fifty five studies, covering at least 30 weed species, have been published since 1995, presenting evidence of the impact of weeds on ecosystem structure and function. These, plus the 21 listed in Adair and Groves (1998), take the number of Australian studies to over 70. However, the available evidence covers

only a small subset of the possible measures of impacts. Grice *et al.* (2004) list 24 papers that measure some impacts of particular environmental weeds in Australia. The list includes 20 papers that report investigations of 14 naturalised plant species, and four that deal with Australian species that are invasive in Australia but outside their native range. Only seven of the 20 Weeds of National Significance (WoNS) are included in the list with these being covered by ten papers.

Burgman *et al.* (2007) point out that many threatening processes, including weed invasion, are poorly- or non-defined and thus likely to be applied inconsistently in determining which species are threatened. The relative importance of weeds, among the 22 types of threat listed, is not quantified and largely unstudied for almost all threatened species. Without this knowledge it will be impossible to develop management options to mitigate the threats that weeds pose.

It is important to continue adding to the growing body of data on the environmental impacts of invasive plants in Australia. However, it is also vital to derive generalisations about the documented impacts and the underlying processes, in particular to identify those species that are capable of transforming ecosystems.

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